EVENTOS HIDROGEOMORFOLÓGICOS EM PORTUGAL E A SUA ASSOCIAÇÃO COM OS "WEATHER TYPES"

HYDRO-GEOMORPHOLOGIC EVENTS IN PORTUGAL AND ITS ASSOCIATION WITH CIRCULATION WEATHER TYPES

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SUMMARY

In recent years it has been possible to improve the characterization of past floods and landslides that caused human and economic impact in Portugal for the 1865-2015 period. In this regard there is an urge for a more systematic assessment of the atmospheric circulation at the synoptic scale associated to flood and landslide damaging events to correctly characterize the climatic forcing of hydro-geomorphologic risk in Portugal. Here we provide a comprehensive analysis of the atmospheric circulation based on the weather type classification, an automated version of the Lamb weather type procedure, initially developed for the United Kingdom and often named circulation weather types (CWT) and latter adapted for Portugal.

1. Introduction

Extreme precipitation events in the Iberian Peninsula can induce floods and landslides that have often major socio-economic impacts associated to extensive property damage and life losses. In recent years it was possible to improve the characterization of past floods and landslides that caused major human and economic impact in Portugal mainland for the period 1865-2015, through the DISASTER database (Zêzere et al., 2014). This database was built under the assumption that strong societal impacts of floods and landslides are sufficiently relevant to be reported in a fairly consistent way by national and regional newspapers. The DISASTER database contains 150 year-long (1865-2015) detailed information on the location, date of occurrence and societal impacts (fatalities, injuries, missing people, evacuated and homeless people) of each individual hydro-geomorphologic case.

The atmospheric forcing at different time scales is the main trigger for the hydro-meteorological DISASTER events occurred in Portugal. Nevertheless most of these individual events present a wide range of large-scale atmospheric conditions in their genesis. In this regard, there is an urge for a more systematic assessment of the role of meteorological synoptic forcing associated to flood and landslide damaging events, thus allowing to correctly characterize the weather driven forcing of hydro-geomorphologic risk in Portugal. This is one driving force of the FORLAND project funded by the Portuguese Foundation for Science and technology. This work has the following objectives:

(1) To identify and characterize the hydro-geomorphologic DISASTER events that occurred in Portugal mainland during the period 1865-2015;

(2) To analyze the circulation weather types associated to floods and landslides DISASTER events for the same period.

2. Methodology

2.1 Hydro-geomorphologic events

The admittance criteria for the DISASTER database are the following: any flood or landslide that, independently of the number of affected people, caused casualties, injuries, evacuated or homeless people.

A DISASTER case is a unique hydro-geomorphologic occurrence (flood or landslide), which fulfills the DISASTER database criteria and is related to a unique space location and a specific period of time (Zêzere et al., 2014). Flood and landslide DISASTER cases for the period 1865-2015 are represented in Figure 1.

DISASTER cases are grouped in a more restrict number of DISASTER events that share the same trigger mechanism and a certain magnitude in time, which were selected according to the following criteria: (i) include at least a set of 3 DISASTER cases; (ii) include Disaster cases with no more than 3 days without cases; and (iii) include DISASTER cases that are coherent concerning spatial distribution.

Each DISASTER event was characterized with the following attributes: hydro-geomorphologic event type (e.g. landslides [L], floods [F], flash floods [FF], urban floods [UF]); date of occurrence (year, month and days); duration in days; spatial location in GIS; number of fatalities, injured, evacuated and homeless people; and weather type responsible for triggering the event.

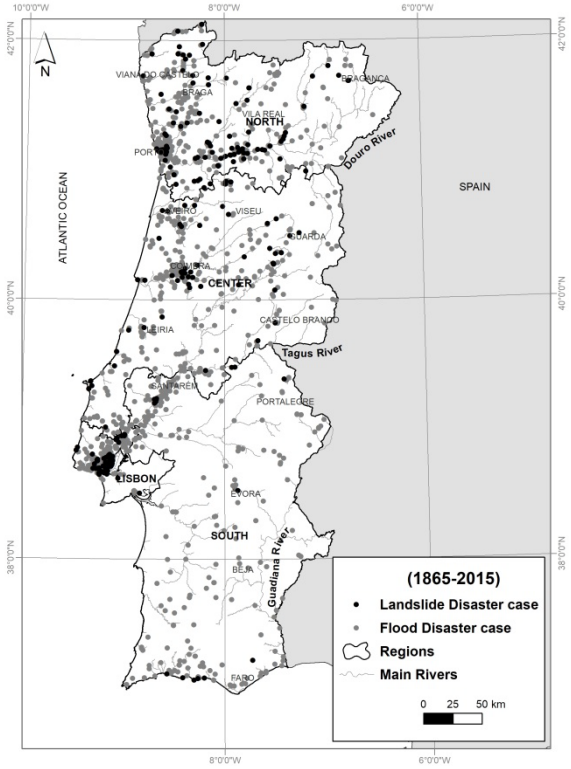

Figure 1. Flood (grey circles) and landslide (black circles) DISASTER cases (1865-2015).

2.2. Circulation weather types

The circulation weather types (CWT) classification used herein corresponds to an automated version of the Lamb weather type procedure and it is based on the corresponding objective Lamb classification defined for the British Isles (Jenkinson and Collison, 1977; Jones et al., 1993) and latter adapted for Portugal (Trigo and DaCamara, 2000). It is based on the use of a set of indices associated to the direction and vorticity of the geostrophic flow.

We computed the daily WT for the 1865–2015 period by means of physical or geometrical parameters based on the daily SLP retrieved from the 20 Century Reanalysis dataset (Compo et al., 2011). To determine the daily CWTs, a set of 16 grid points (5º lat. by 10º long.) centered on the IP was used. While the original work of Trigo and DaCamara (2000) was centered over western Iberia, our grid-points were moved 5◦ to the east in order to center the entire grid in the middle of the IP (the area of this study, 40◦N, 5◦W for central point, Figure 2).

26 different weather types, 10 pure types (NE, E, SE, S, SW, W, NW, N, C, and A) and 16 hybrid types (8 for each C or A hybrid) were identified, using the same methodology as in Trigo and DaCamara (2000).

In addition, CWT dynamical variables (flow strength, vorticity and direction) were used to better understand the impacts of the meteorological conditions in these DISASTER events in Portugal. Finally, CWT was computed for all the days of each Disaster event.

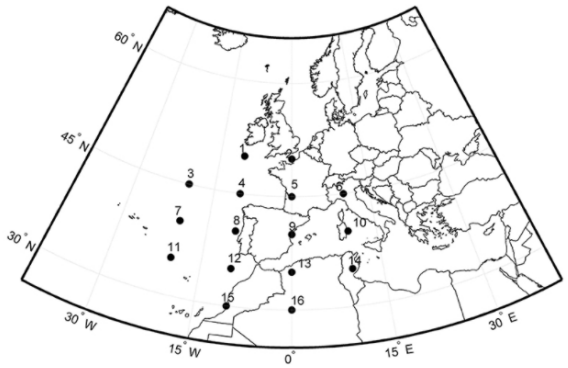

Figure 2. 16 SLP grid points of the 20C Reanalysis (1871-2014).used in the CWTs computation

3. Results

3.1. Hydro-geomorphologic events

In total, the DISASTER database includes 130 events that generated societal impacts in Portugal (938 fatalities and 40827 homeless people) (Table 1). DISASTER events include 96.5% of the total number of displaced people and only 74.7% of the total number of fatalities recorded in the DISASTER database.

On average, DISASTER events last for 3.4 days and record 10.9 DISASTER cases.

The event of 5-16 February of 1979 is on the top of the Disaster events that caused the highest number of affected people (18578) in Portugal, mainly as a consequence of large floods in the Tagus basin (Table 1). This event was caused by several consecutive days characterized by CWTs with a western component.

Flash floods are often associated to Cyclonic type CWTs, like for example the flash flood event of 25-26 November 1967 (Table 1), that generated the deadliest storm of the 20th century in the Lisbon Metropolitan Area (Trigo et al., 2016).

3.2. Circulation Weather Types

Annual average frequency of CWT computed for the entire period 1865-2015 (Figure 3), shows that Anticyclone was the most frequent CWT (33%). It is well known that most of the precipitation is produced by just a few CWT that contribute to a large percentage of the monthly precipitation (Trigo and DaCamara, 2000). For the IP we have shown that the most efficient the Cyclonic cluster types throughout the year, and the Directional (those with a western component) being also efficient precipitation generators in winter months (Ramos et al., 2014)

Table 1. Extract of the DISASTER database events characteristics

ID	Event type	Date	CWT	Nr. Days	Disaster cases	Fatalities	Injured	Evacuated people	Displaced people	Affected people
95	F;FF;L	5-16Feb1979	W,AW,SW,CW	12	67	8	3	4244	14322	18578
94	FF;UF;L	28Feb-4Mar1978	W,SW,CW	7	35	0	5	233	4758	4996
97	FF;UF;L	18-19Nov1983	E,S	2	37	18	0	255	3239	3512
73	F;UF	31Jan-1Feb1961	SW,C	2	34	0	1	204	3141	3348
101	FF;UF;L	15-26Dec1989	SW,CSW,AW(…)	12	36	1	5	355	1960	2321
82	F;FF;UF;L	18-24Feb1966	SW,W,A	7	41	4	22	137	1924	2087
84	FF;UF	25Nov1967	C	2	67	522	330	304	885	2042
59	F;UF	14-19Dec1955	W,SW	6	13	2	0	37	2000	2039
8	F;FF;UF;L	20-28Dec1909	W,SW,A	9	83	37	4	679	478	1216
35	F;UF;L	2-6Jan1940	CSW,CW,W,AW	5	26	7	3	35	1043	1088
114	F;L	26-27Jan2001	W,NW	2	28	6	5	402	570	983
104	FF;UF;L	6-9Jan1996	SW,W,CSW,	4	37	4	0	249	558	861
88	F;L	12-18Mar1969	SW,W	7	18	3	2	48	769	822
43	UF	18Nov1945	CS	1	11	2	0	259	444	705
45	F;FF;UF	18-22Dec1945	W,SW,CW,W	5	14	9	3	52	417	481
(…)										
Total					**1411**	**938**	**573**	**12087**	**40827**	**54528**
%Disaster cases					**71.7**	**74.7**	**62.8**	**81.1**	**96.5**	**91.6**

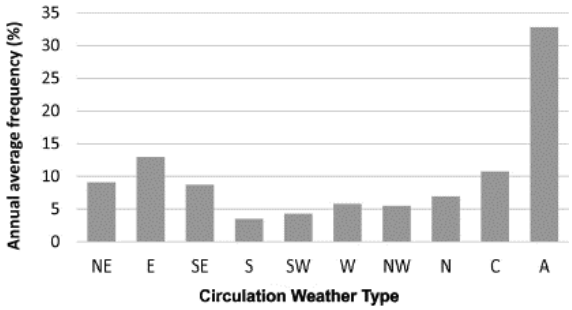

Figure 3 - Annual average frequency of CWT in the period 1865-2015.

The relationship between the CWTs and the hydro-meteorological events shows that the C, W and SW are frequently associated with floods and landslides that generated major impacts in Portugal (Table 1).

The percentage of days with DISASTER events according to the main CWT groups (cyclonic, western component, eastern or southern component, northern component and anticyclonic component) is summarized by districts in Figure 4. The districts of Lisboa and Porto recorded the highest number of days DISASTER events (107 days each). The percentage of days with DISASTER events per CWT shows that the western component (SW, W, NW) is present in more than 70% of the days in the districts of Aveiro, Braga, Vila Real and Porto. On contrary, the districts located in the South (Faro and Beja) recorded the highest percentage of days with DISASTER events generated by CWTs with an eastern or southern component (E, SE, S).

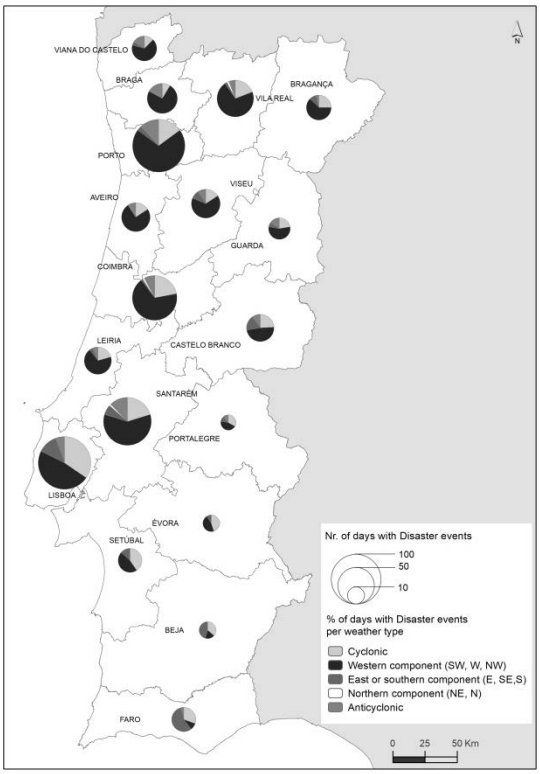

Figure 4. Percentage of days with DISASTER events per CWT and district (1865-2015).

Finally, cyclonic CWT corresponds to more than 30% of the days with DISASTER events in the districts of Évora, Setúbal, Beja, Lisboa, Portalegre and Faro.

It is important to note that the Cyclonic CWT was found to be associated to 65% of the fatalities generated by DISASTER events, while the western component types (SW, W, NW) are associated to 62% of DISASTER events that caused homeless people.

4. Conclusions

We have provide a novel approach establishing the links between the frequency of different circulation weather types (CWTs) associated to floods and landslides included in the long-term DISASTER database of hydro-geomorphological events for the same period in Portugal mainland. DISASTER events catalog and the corresponding CWT that characterizes them will be available online in the FORLAND project website (http://www.ceg.ulisboa.pt/forland/). Also this work contributes to the construction of risk profiles for the Portuguese municipalities by combining indexes expressing the hydro-geomorphological disasters driving forces (e.g. the climatic causes of events; the territorial physical constrains; the land use changes and exposure; and the territorial vulnerability) to contribute to disaster risk management involving local stakeholders, to adaptation strategies to reduce disaster risk and also guidelines for spatial planning.

Acknowledgements

This work was supported by the project FORLAND – Hydrogeomorphologic risk in Portugal: driving forces and application for land use planning [PTDC/ATPGEO/1660/2014] funded by the Portuguese Foundation for Science and Technology (FCT), Portugal. A. M. Ramos was also supported by a FCT postdoctoral grant (FCT/DFRH/ SFRH/BPD/84328/2012).

References

Compo, G.P., J.S. Whitaker, P.D. Sardeshmukh, N. Matsui, R.J. Allan, X. Yin, B.E. Gleason, R.S. Vose, G. Rutledge, P. Bessemoulin, S. Brönnimann, M. Brunet, R.I. Crouthamel, A.N. Grant, P.Y. Groisman, P.D. Jones, M. Kruk, A.C. Kruger, G.J. Marshall, M. Maugeri, H.Y. Mok, Ø. Nordli, T.F. Ross, R.M. Trigo, X.L. Wang, S.D. Woodruff, and S.J. Worley (2011) The Twentieth Century Reanalysis Project. Quarterly J. Roy. Meteorol. Soc., 137, 1-28. http://dx.doi.org/10.1002/qj.776.

Jenkinson, A.F. and Collison, F.P. (1977) An initial climatology of gales over the North Sea. Synoptic Climatology Branch Memorandum No. 62, Meteorological Office, Bracknell.

Jones, P.D., Hulme, M. and Briffa, K.R. (1993) A comparison of Lamb circulation types with an objective classification scheme. Int. J. Climatol. 13, 655-663.

Ramos, A. M., Cortesi, N. and Trigo, R. M.: Circulation weather types and spatial variability of daily precipitation in the Iberian Peninsula (2014) Front. Earth Sci., 2(October), 1–17, doi:10.3389/feart.2014.00025.

Trigo, R. M. and DaCamara, C. C.: Circulation weather types and their influence on the precipitation regime in Portugal (2000) Int. J. Climatol., 20(13), 1559–1581, doi:10.1002/1097-0088(20001115)20:13<1559::AID-JOC555>3.0.CO;2-5

Trigo, R. M., Ramos, C., Pereira, S. S., Ramos, A. M., Zêzere, J. L. and Liberato, M. L. M. L. R (2016) The deadliest storm of the 20th century striking Portugal; flood impacts and atmospheric circulation, J. Hydrol., 541(Special Issue: Flash floods & landslide), 597–610, doi:10.1016/j.jhydrol.2015.10.036.

Zêzere, J. L., Pereira, S., Tavares, A. O., Bateira, C., Trigo, R. M., Quaresma, I., Santos, P. P., Santos, M. and Verde, J (2014) DISASTER: a GIS database on hydro-geomorphologic disasters in Portugal, Nat. Hazards, 72(2), 503–532, doi:10.1007/s11069-013-1018-y.